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## *W* and *Z* boson precision measurements at ATLAS

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**Summary.** — The large statistics reachable at LHC and the clear signature of leptonic decays allow to perform high-precision measurements of *W* and *Z* bosons. In this contribution the most recent results are presented on *W/Z* studies at the centre-of-mass energy of 13 TeV. In addition, the first *W* mass measurement performed at LHC at  $\sqrt{s} = 7$  TeV is also described.

### 1. – *W* and *Z* inclusive production cross-section and their ratios at $\sqrt{s} = 13$ TeV

Thanks to the high-precision reachable in their measurements, the *W* and *Z* vector bosons are considered Standard Model (SM) candles, also used for detector alignment and calibration. *W/Z* are important benchmarks for the understanding of strong (QCD) and electroweak (EW) processes and, from the comparison with available NNLO theoretical calculations, allow to constrain proton PDFs. The *W* and *Z* production cross-sections have been measured with early Run 2 data, corresponding to a luminosity of 81 pb<sup>−1</sup>. *W*<sup>+</sup>, *W*<sup>−</sup> and *Z* cross-sections have been determined separately in the muon and electron channel with a cut-and-count technique [1] and found to be compatible, testing the lepton universality. The measurements are in agreement with theoretical calculations based on NNLO QCD with NLO EW corrections. The results have a global luminosity uncertainty of 2.1%, while the remaining experimental uncertainties in the *W*<sup>±</sup>- and *Z*-boson channels are found to be under 3% and 1%, respectively.

The cross-section ratios *W*<sup>+</sup>/*W*<sup>−</sup>, *W*<sup>±</sup>/*Z* and *t* $\bar{t}$ /*Z* benefit from the reduction of several experimental uncertainties and from the cancellation of the luminosity systematics. The *W*<sup>+</sup>/*W*<sup>−</sup>, *W*<sup>±</sup>/*Z* and *t* $\bar{t}$ /*Z* ratios are sensitive to the PDFs of valence quarks, strange sea quark and gluons, respectively. In particular,  $\sigma_{W^+}/\sigma_{W^-}$  is measured with

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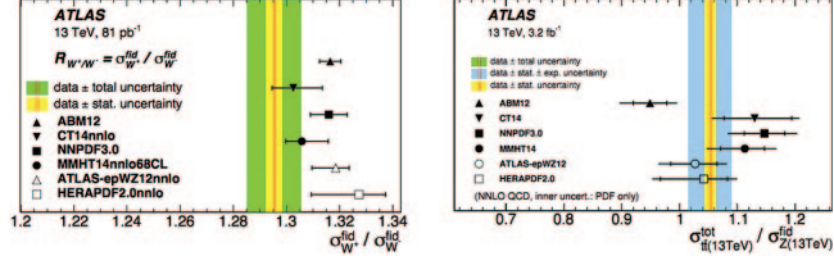


Fig. 1. – Ratios of  $W^\pm/Z$  (left) and  $t\bar{t}/Z$  (right) cross-sections compared to predictions with different PDF sets. The two measurements have been performed with data collected at 13 TeV corresponding to a luminosity of  $81 \text{ pb}^{-1}$  (left) and  $3.2 \text{ fb}^{-1}$  (right).

an uncertainty of 0.8%, which allows to discriminate among the various PDFs presented in fig. 1 (left).

The measurement of the  $t\bar{t}/Z$  ratio has been performed at the different centre-of-mass energies of  $\sqrt{s} = 7, 8$  and 13 TeV [2], exploring different Bjorken- $x$  regions. Measured with a luminosity of  $3.2 \text{ fb}^{-1}$ , the  $t\bar{t}/Z$  ratio at 13 TeV (fig. 1 (right)) shows excellent agreement with predictions, confirming that such measurement could be used to normalise cross-section measurements at different centre-of-mass energies. The results have a significant power to constrain the gluon distribution function at Bjorken- $x \sim 0.1$  and the total light-quark sea at  $x < 0.02$ , as demonstrated in [2] from a profiling analysis using the ATLAS-epWZ12 PDF set.

## 2. – $Z$ + jets production at $\sqrt{s} = 13 \text{ TeV}$

The  $Z$  boson produced in association with jets fits in this context. Dominated by strong interactions, it is a sensitive probe of the different Monte Carlo descriptions. The  $Z$  + jets events also constitute a non-negligible background for studies of the Higgs boson and in searches of new phenomena, where typically the jet multiplicities and kinematics are exploited to achieve a separation of the signal from the SM  $Z$  + jets process.

The  $Z$  + jets production has been measured with 2015 data corresponding to a luminosity of  $3.2 \text{ fb}^{-1}$  [3]. The fiducial cross-sections for  $Z + \geq 0$ –7 jets have been measured

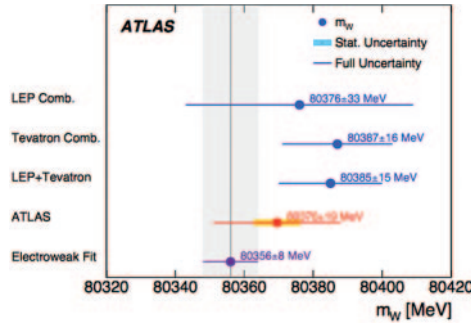


Fig. 2. – Comparison of the ATLAS measurement of the  $W$  mass with the SM predictions from the global fit, and with the combined LEP and Tevatron results.

with a precision ranging from 4% to 30%. Parton level distributions have been determined as a function of jet multiplicity and jet kinematic variables. The results show good agreement with the fixed-order  $Z + \geq 1$  jet Njet calculations, while MG5\_aMC + Py8 CKKW, which is based on LO matrix elements, models a too-hard jet spectrum. There is some evidence of deviations for high jet multiplicity, explained considering that the emission of partons for  $Z + \geq 4$  jets is modelled by parton shower.

### 3. – $W$ mass measurement at $\sqrt{s} = 7$ TeV

The  $W$  mass is a fundamental parameter of the SM and at NLO it contains corrections due to top and Higgs electroweak loops, depending on  $m_t^2$  and  $\ln(m_H)$ . In the global fit contest, constraints on new physics are limited by the precision on the  $W$  mass.

ATLAS performed the first measurement at LHC at  $\sqrt{s} = 7$  TeV, corresponding to a luminosity of  $4.6 \text{ fb}^{-1}$  [4]. At LHC the measurement is particularly challenging, since 25% of the  $W$  production originates from the second generation of quarks, which affect the  $p_T$  distribution of the  $W$  boson: as a consequence, the mass measurement is sensitive to the  $s$ - and  $c$ -quark PDFs of the proton. The  $W$  events are selected requiring a high- $p_T$  lepton and measuring the  $W$  recoil, to reconstruct the neutrino transverse momentum. The  $W$  mass is measured from fits on templates of the  $W$  transverse mass and the lepton transverse momentum, generated from Monte Carlo samples with different  $W$  mass values. In order to validate the analysis strategy and to constrain recoil and lepton calibrations, the  $Z$  mass has been measured with the same method. The combined result  $m_W = (80370 \pm 19) \text{ MeV}$  is in agreement with the LEP+Tevatron world average and with SM expectations (fig. 2). The result is dominated by the theoretical uncertainty, whose major sources are the QCD scale and the PDFs evolution.

### 4. – Conclusions

At the centre-of-mass energy of  $\sqrt{s} = 13$  TeV, several  $W/Z$  measurements have been performed, reaching a precision less than 3% (1%) in the inclusive  $W(Z)$  cross-sections. An even higher sensitivity has been reached in the determination of the cross-sections ratios: in particular,  $W^+/W^-$  has been measured with a precision of 0.8%. The  $Z + \text{jets}$  production has been studied up to high jet multiplicity and found in good agreement with NNLO calculations. ATLAS performed the first measurement of the  $W$  mass at  $\sqrt{s} = 7$  TeV, obtaining a value in agreement with the world average and consistent with SM expectations, the uncertainty being dominated by the theoretical contribution.

### REFERENCES

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